

**Winter-to-Spring Transition in Europe 48-54°N: From Temperature Control by Advection to Control by Insolation**

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**Abstract.** As established in previous studies, and analyzed further herein for the years 1988-1998, warm advection from the North Atlantic is the predominant control of the surface-air temperature in northern-latitude Europe in late winter. This thesis is supported by the substantial correlation  $C_{ti}$  between the speed of the southwesterly surface winds over the eastern North Atlantic, as quantified by a specific Index  $I_{na}$ , and the 2-meter level temperature  $T_s$  over central Europe (48-54°N; 5-25°E), for January, February and early March. In mid-March and subsequently, the correlation  $C_{ti}$  drops drastically (quite often it is negative). The change in the relationship between  $T_s$  and  $I_{na}$  marks a transition in the control of the surface-air temperature. As (a) the sun rises higher in the sky, (b) the snows melt (the surface absorptivity can increase by a factor of 3.0), (c) the ocean-surface winds weaken, and (d) the temperature difference between land and ocean (which we analyze) becomes small, absorption of insolation replaces the warm advection as the dominant control of the continental temperature. We define the onset of spring by this transition, which evaluated for the period of our study occurs at pentad 16 (Julian Date 76, that is, March 16). The control by insolation means that the surface is cooler under cloudy conditions than under clear skies. This control produces a much smaller interannual variability of the surface temperature and of the lapse rate than prevailing in winter, when the control is by advection.

Regional climatic data would be of greatest value for agriculture and forestry if compiled for well-defined seasons. For continental northern latitudes, analysis presented here of factors controlling the surface temperature appears an appropriate tool for this task.

## 1. Introduction

Three basic problems in climate studies, evaluating trends, interannual variability, and oscillation patterns (such as the North Atlantic Oscillation), attract intense attention in recent years. These problems are closely interrelated: in assessing a trend, interannual fluctuations constitute the noise, and errors are likely to arise when attempting to evaluate a trend for a time period that coincides with a segment of an oscillation. Mathematical tools for such studies are well established in the case of stationary time series (Wiener, 1949). It is an open question to what extent climate data can be regarded as stationary. Phenomena such as a large volcanic eruption clearly introduce transitions in the climatic record, e. g., 1991 Mt. Pinatubo eruption (Angell, 1996; Abdalati and Steffen, 1997).

In these challenging tasks of quantitatively evaluating trends or detecting oscillatory patterns in climate time series, it is critically important to check whether the region of interest exhibits a uniform "behavior" in the season under study. Many valuable studies can be faulted to some extent in this respect. For instance, Ross et al. (1996) analyze from radiosonde data seasonal trends in eight selected northern-latitude regions. The regions were carefully delineated (as boxes in latitude and longitude) for uniformity of the trends (generally warming, but cooling in the eastern Canada - Greenland region). The greatest warming was reported in eastern Siberia for the December-February quarter. Subsequent calculations (R. Ross, NOAA, personal communication) established the February trend at almost 2°C per decade, that is, substantially higher than the 1.2°C per decade December-February average reported in 1996. This very high warming trend toward the end of winter may significantly advance the snow-melt date in this frigid region.

From phenological events, such as leaf unfolding, Menzel and Fabian (1999) report that the growing season increased by 10.8 days in the 30 years of their observations since 1960. Numerous European stations, from Macedonia to Scandinavia, provided the data. However, there was no attempt to identify and to delineate regions for uniformity of trend: the Balkans experienced a

decrease in the growing season, so that the increase in the more northern latitudes was appreciably higher than that reported for the entire region of the study. Menzel and Fabian (1999) state that the inferred temperature increase is one of the direct effects of the global warming.

The springtime data series of Menzel and Fabian (1999) reveal an advancement of spring by 0.2 days per year. Detecting a trend to early spring over a large region is a significant finding, with important implications. Placing this finding directly in the global framework (global warming) is unlikely to be totally wrong, but it is simplistic. The reported cooling in the Balkans indicates that regional trends are controlled by regional effects, such as changes in the circulation. We should examine the processes that *directly control* the onset of spring in a region.

A recent study (Otterman et al., 1999) established that advection from the relatively warm ocean surface acts as control of the surface-air temperature in northern-latitude Europe in late winter. When circulation patterns produce strong surface southwesterlies over the eastern North Atlantic, positive surface-temperature anomalies are reported over Europe, from northern France all the way to the Ural foothills. Thus, in late winter the direct key to elevated continental temperature lies in the warm advection from the North Atlantic. This relationship does not apply in spring or summer.

We examine a concept that the onset of spring in Europe at continental northern latitudes, 48-54°N; 5-25°E, can be specified by the transition in the control of the surface-air temperature. When ocean-to-land temperature difference becomes small, advection of warm marine air loses its dominant role in raising the continental surface temperature. As the midday sun rises higher in the sky, this role is taken over by the absorption of insolation. Clear conditions tend then to induce a warm surface, and advection of moist marine air can have a negative impact on the surface temperature through an increase in cloudiness and a reduction in the surface solar irradiance.

We conduct here pentad-by-pentad examination, even though a 5-day time-interval is not generally suitable for climate analysis, where monthly or seasonal statistics are compared. The choice of this time-interval was dictated by our aim, to analyze relations between three parameters (ocean-surface wind vector, continental air temperature, and lapse rate), and to examine how these relations change with the Julian date. Thus, pentad analysis is a compromise between the conflicting requirements: reducing the "weather noise", yet attempting to detect discrete transitions in an 11-year record. Monthly analysis is definitely too coarse a resolution for our purpose.

## 2. Extraction of the study parameters from the ECMWF and SSM/I datasets

The pentad-by-pentad air-temperature data for central Europe, 48-54°N; 5-25°E, both at the surface and at 500 mb (averages of 0000 and 1200 UTC), are extracted from the ECMWF dataset (part of the ECMWF/WCRP Global Atmospheric Data Archive). We also extract from this dataset the 2-meter level temperature in the area of the North Atlantic 36-50°N; 20-10°W.

This "box" in the West European Basin was selected for computing our wind speed Index *Ina* (after trying out other "boxes"; the trials indicated that almost any adjoining "box" would produce similar results), designed to quantify the warm advection into Europe. *Ina* is computed from the Special Sensor Microwave Imager, SSM/I, dataset, where the direction is assigned to the microwave measurements of the ocean-surface wind speed by Variational Analysis Method (Atlas et al., 1996). Comparisons with measurements of wind vectors withheld from the analysis indicate that the technique provides accurate speed *and* direction data. The more recent update of this dataset offers a reliable record for the 1988-1998 period, appropriate for climate analysis

(Otterman et al., 1999). In this SSM/I dataset the "box" 36-50°N; 20-10°W contains 40 grid points at which the SSM/I measurements are reported for each satellite pass. Any gap in the SSM/I data is filled by inserting information from the ECMWF dataset. Computing  $I_{na}$  involves determining the wind direction at each grid point. If the direction is from the quadrant 180° to 270°, then this point contributes to the southwesterly speed average in the "box" for a satellite pass (if the direction at a point is not southwesterly, the contribution is zero). The average for all the satellite passes in a pentad is reported as our Index  $I_{na}$ .

### 3. Analysis of Correlations and Interannual Variability

The surface-air temperature ( $T_s$ ) and the 500 mb temperature ( $T_{500}$ ) for central Europe (from the ECMWF dataset), and the Index  $I_{na}$  (from the SSM/I dataset) are here analyzed for pentads 1 to 36 (that is, for late winter, spring, and early summer), for the years 1988 to 1998. We examine relations between  $T_s$ , a lapse rate parameter ( $\Delta$ ) defined as  $\Delta = T_s - T_{500}$ , and  $I_{na}$ .

The two extracted temperatures,  $T_s$  in central Europe and  $T_{na}$  in eastern North Atlantic, shown versus the pentad number in Fig. 1A, increase from winter to spring, but  $T_{na}$  obviously increases much more slowly than  $T_s$ . The correlations  $C_{Ti}$  and  $C_{T\Delta}$ , of  $T_s$  with  $I_{na}$  and with  $\Delta$ , respectively, are shown in Fig. 1B. We note that both correlations take substantial values for pentads 1 to 15, but drop drastically for pentads 16 and higher, when the correlations are occasionally negative. We interpret this change as a switch in the control of the surface-air temperature in central Europe, from the control by low-level advection in winter, to the control by absorption of shortwave radiation by the surface in spring. The transition to spring occurs at pentad 16 (that is Julian Date 76, or March 16), as determined by our approach, which does not really offer one-day resolution. The temperature  $T_s$  rises to 3.50°C in pentad 16 (Fig. 1A). In Fig. 1C, the standard deviations of  $T_s$ ,  $\Delta$ , and  $I_{na}$  are shown also versus the pentad number. The interannual variability of these three parameters is much lower in spring than in late winter, but the decrease is more gradual than in the case of  $C_{Ti}$  and  $C_{T\Delta}$ .

In the spring, the continental temperature is controlled by increasing solar insolation. When the snows melt, the surface absorptivity (co-albedo) can increase by a factor of 3.0. The absorption of insolation by the surface becomes dominantly important, which can be shown by examining specific scenarios. For instance, warming prevailed in pentad 18 (last pentad in March) in 1997, coincident with clear skies. The value of  $I_{na}$  was low for this pentad, suggesting absence of advected marine air. The prevailing conditions, adverse to cloud formation, produced high insolation and thus elevated the surface temperature.

To further demonstrate the dependence on insolation, the anomaly ( $A_{st}$ ) of the skin surface temperature and the anomaly ( $A_{cf}$ ) of the cloud fraction (from the TOVS Pathfinder dataset, Susskind et al., 1997), at 50 and 60° N, are plotted versus longitude, for July 1988 in Fig. 2. Clearly  $A_{st}$  and  $A_{cf}$  are negatively correlated (over the continents). In July, the shortwave effects of clouds (reducing insolation) is more important than the longwave effect (reducing the longwave losses), and thus the surface tends to be cooler under cloudy conditions than under clear skies. Advection of marine (moist) air, by fomenting cloud formation, can have a negative impact on the surface temperature in summer, in contrast to winter.

### 4. Discussion and Conclusions

The customary definition of the four seasons, in terms of solstices and equinoxes (at fixed dates), is linked to the solar elevation at local noon. Rather obviously, this definition has quite different meaning in the tropics than at high latitudes. For climatological data compilation, the four seasons are routinely modified by advancing the start of each season by about three weeks, that is, December-February for winter, etc. (Angell, 1990, for instance). Global or hemispheric characterization at such fixed-dates

FIG. 1

FIG. 2

has no direct meaning for a specific area. Poleward of 35°, average date of the snow melt is a more pertinent specification of the onset of spring for agriculture and forestry in the region. In a semi-arid country, such as Israel (where a killing frost is a rare event) temperature is not as important climate parameter as precipitation. Partition into a rainy and a dry season is a natural choice. The rainy season should be further divided into early rains, mostly convective, and late rains, mostly large-scale. The mechanisms underlying these two types of precipitation are different, and thus, not surprisingly, statistical analysis (such as day/night partitioning of rain events, or evaluation of decadal trends) for one type has no significance for the other type (Otterman and Sharon, 1979; Otterman et al., 1990).

We specify here the onset of spring in central Europe by the shift in the relationship between the continental surface-air temperature and the North Atlantic surface winds. When the ocean winds in our selected "box", just to the west of France, are from the southwest and strong (as quantified by  $I_{na}$ ), warm advection of marine air in a low-level flow raises the surface-air temperature on the continent in winter. The correlation  $C_{ti}$  between the  $T_s$  and  $I_{na}$  is substantial. Since surface air is most directly affected by the low-level inflow of air warmed by contact with the relatively warm ocean, the lapse rate increases. Thus, we also find in winter substantial correlation  $C_{t\Delta}$  between  $T_s$  and the lapse rate parameter  $\Delta$ . A steeper lapse rate is commonly associated with a lower OLR (for a given surface emission), and can reinforce, by a reduction of the net heat loss (surface emission minus absorption of downwelling sky emission) the near-surface warming by the southwesterly airflow. The contribution of such regional reinforcing cannot be quantitatively assessed, but the increases in atmospheric water vapor and temperature lapse rate are likely to enhance significantly the near-surface warming through effects similar to the water-vapor and lapse-rate feedbacks found by Hu (1996) from the mid-latitude seasonal cycle, and by Wetherald and Manabe (1988) with doubled  $CO_2$  in a GCM. Hu (1996) points out that these two mechanisms are more important in the lower troposphere than in the upper troposphere.

These relationships hold in force in late winter, when the North Atlantic winds are strong, and the ocean surface is much warmer than the continent. But this temperature difference becomes small in late March (as can be seen in Fig. 1A). As the midday sun rises higher over the horizon, and as the surface gradually becomes snow-free (or partially snow-free; the surface albedo drops sharply for off-zenith shortwave illumination even when snow covers the ground, if trees are not snow-covered, see Otterman et al., 1984). Thus, we observe (Fig. 1B) a shift to low values of  $C_{ti}$  and  $C_{t\Delta}$ . Defining the onset of spring by this shift for the period 1988-1998, spring arrives in central Europe on Julian Date 76, or March 16. The surface-air temperature  $T_s$  rises to 3.50°C in pentad 16, which implies that the arrival of spring in Europe determined by our criterion approximately coincides with the snow melt in the region. We observe that the interannual variability (standard deviation) of  $T_s$ ,  $\Delta$  and  $I_{na}$ , is appreciably lower in spring than in late winter.

As Bryson and Lahey (1958) point out, it is appropriate to develop "a calendar whose basic seasons are determined by singular changes [for the given region] of the state and action of the atmosphere". When the lengths of seasons undergoes a change, as reported by Menzel and Fabian (1999) for instance, then "seasonal data, with length of seasons itself a variable, might be ...appropriate", as suggested by Otterman (1976) in conjunction with climatic changes brought about by changes in cloudiness over the oceans.

We suggest a calendar for continental northern latitudes based on the factors controlling the surface-air temperature, the key parameter for crop cultivation at these latitudes. For our region, March is the transition month, encompassing two distinct seasons. The correlation 0.65 between the southwesterlies over the eastern

North Atlantic and the surface-air temperature in France, calculated for March by Otterman et al. (1999), is not truly a meaningful measure of the link between those two parameters, because in late March the link differs from that prevailing in early March. The small section of the globe that we study is representative of at least half-a-hemisphere, an 180° belt in longitude, namely the Eurasian continent (west of the Urals from our studies; east of the Urals from the study by Rogers and Mosley-Thompson, 1995). However, in the eastern Canada-Greenland region some region-specific processes are apparently at work, which produce decadal trends opposite to those for Asia (Ross et al., 1996), and interannual fluctuations opposite to those for Europe (our observations of February 1997 versus 1996). This "contrarian" region is limited in its geographical extent, and thus our small section probably is indicative of the hemispheric variations, such as analyzed by Hurrell (1996).

Climate data would be of greatest applicability for agriculture /forestry, if compiled for well-defined seasons, specific to a given region, determined from an analysis such as ~~the~~ given here.

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**Figure Captions**

- Fig. 1 Continental surface-air temperature  $T_s$ , and 2-meter air temperature  $T_{na}$  over the area used for computation of the wind Index  $I_{na}$ , in 2A; correlation of  $T_s$  with  $I_{na}$ ,  $C_{ti}$ , and with the lapse rate parameter  $\Delta$ ,  $C_{t\Delta}$ , in 2B; root mean-square standard deviations  $\sigma$ ,  $\sigma_{\Delta}$ , and  $\sigma_i$ , in 2C; all versus the pentad number.
- Fig. 2 Anomaly of the surface skin temperature  $A_{st}$  and of the cloud fraction  $A_{cf}$  for July 1998, at latitudes of 50 and 60°N, versus longitude.

**Index Terms**

- 1610 Atmosphere  
 1620 Climate dynamics  
 1635 Oceans  
 1640 Remote sensing

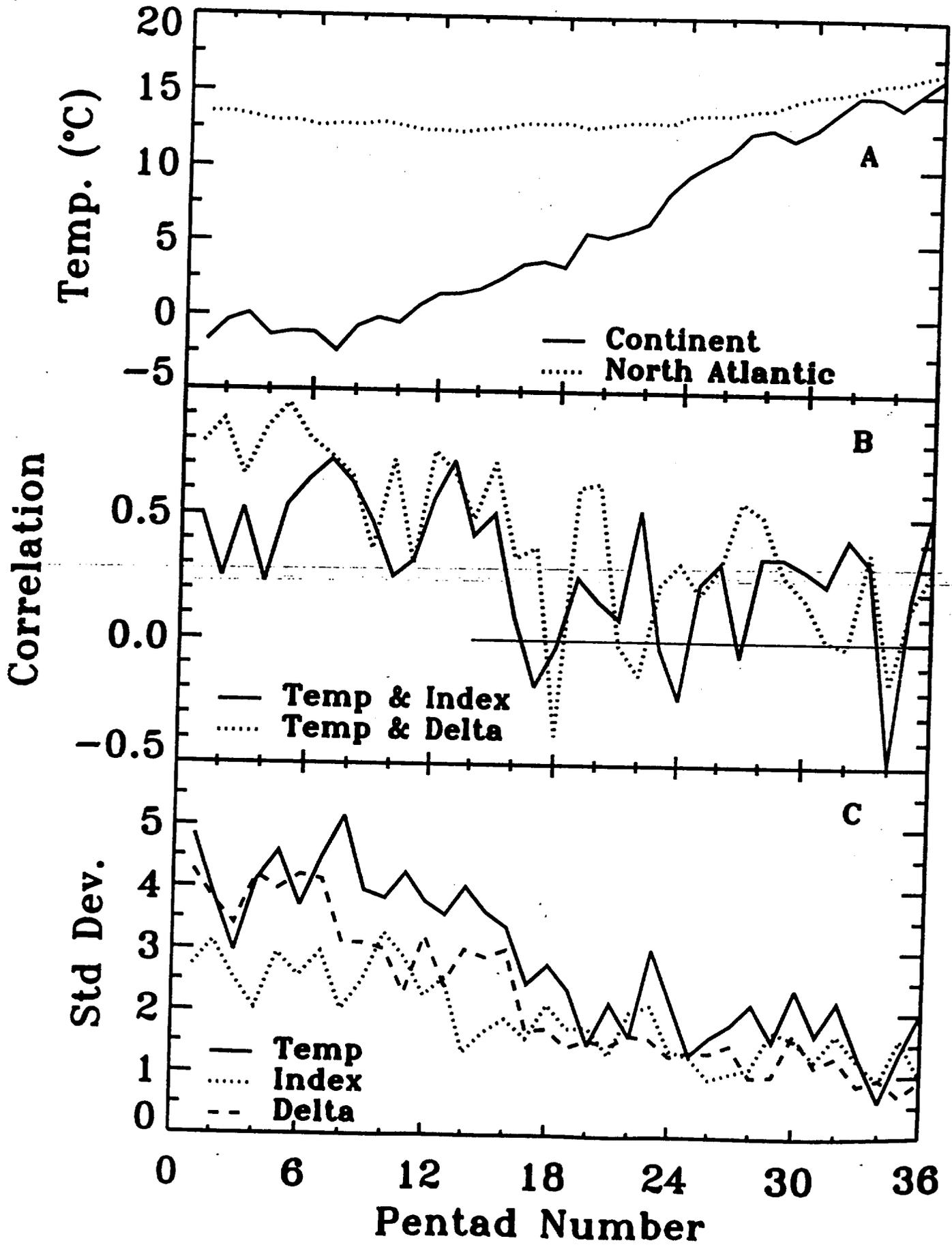


FIG. 1

# Field minus July 1998 Climatology

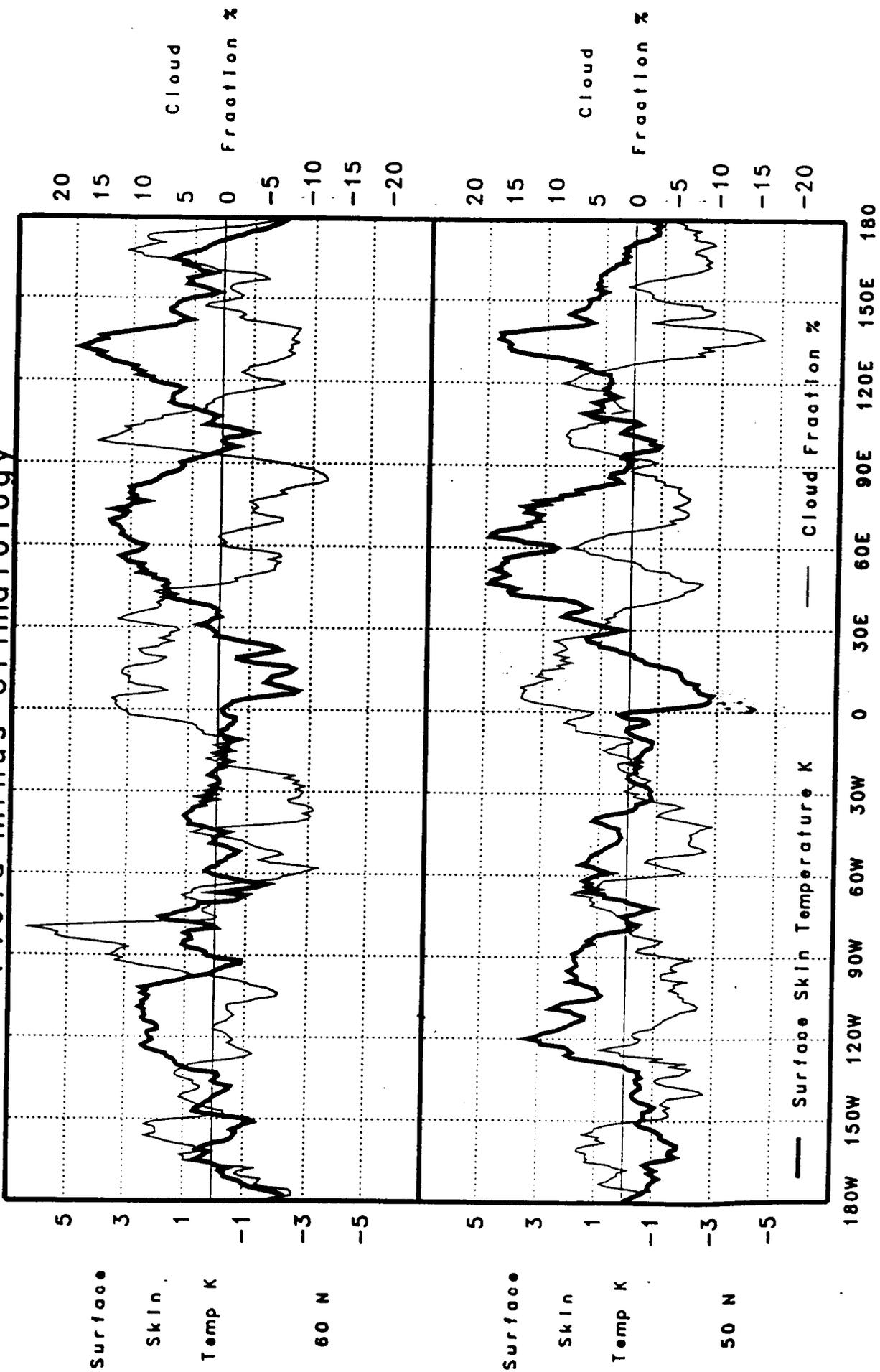


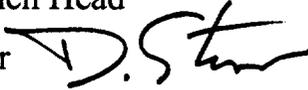
FIG.2

# MEMORANDUM

TO: 913/Branch Head

December 29, 1999

FROM: 913/Starr



SUBJECT: Authorship on Paper

Dr. Joseph Otterman, a contractor, is the appropriate first author on the paper described below. Dr. Otterman was primarily responsible for the content and conduct of the research that is reported.

*P.S., will permission to publish forms too!*

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Title: Winter-to-Spring Transition in Europe 48-54°N: From Temperature Controlled by Advection to Control by Insolation

Authors: J. Otterman, J. Ardizzone, R. Atlas, H. Hu, J.C. Jusem and D. Starr

Journal: AGU-Geophysical Research Letters

Summary: Climate studies typically analyze data on a seasonal basis. However, definitions of the seasonal boundaries are somewhat arbitrary, e.g., winter as December-January-February. In this study of the 1988-1998 period, statistical analysis of correlation between low level winds over the Atlantic Ocean and surface air temperature anomalies over Europe demonstrate a clear mid-March transition from a winter regime where warm anomalies are associated with strong southwesterly maritime advection to a spring regime where warm anomalies are associated with clear skies and not with advection of maritime air. The basic point of the paper is that use of a more objective, and regionally specific, definition of the seasons would likely increase the signal (by not mixing "apples and oranges") seen in climate analyses and, thus, the utility of such analyses for applications such as agriculture and forestry.

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